Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings

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The Issue

Usually, outdoor air is cleaner than indoor air, as the air inside buildings contains combustion byproducts from stoves and furnaces, vapors from cleaning products, cooking odors, and many other types of pollution. Sufficient fresh air from outdoors must enter the building and sufficient indoor air must escape, or the indoor air will become uncomfortable and unhealthy. Yet excessive air exchange wastes energy (and costs money), because the air must be heated or cooled to a comfortable indoor temperature.

Much is known about air exchange rates in detached, single-family houses, but little is known about air exchange rates in commercial buildings, and even less is known about multi-family housing units such as apartment buildings, condominiums, and row houses. Likely, many of these buildings have unnecessarily high (and thus costly) air exchange rates, but some may have air exchange rates that are too low and may even be acutely dangerous by allowing buildup of carbon monoxide and other toxics. Better data are needed on the statistical distribution of air exchange rates in multi-family and commercial buildings. Such information would provide a starting point for optimizing indoor air quality in these buildings, leading to improved health and energy savings.

Moreover, a better understanding of the air exchange rates for commercial and multi-family buildings would help authorities determine proper “shelter in place” guidelines in the event of a toxic chemical release, whether by industrial accident or terrorist attack. Without knowing the statistical distribution of air exchange rates, public health officials can only guess how long indoor air will remain safer than outdoor air in the event of a disaster.

Project Description

This project had five main tasks:

1. Review the literature and public data sources related to indoor-outdoor air exchange for “commercial” buildings (businesses, schools, public buildings, and other nonresidential buildings), apartments, and other multi-family structures in California and elsewhere.
2. Contact experts who have tested or measured air exchange rates. Ask about sources of private data, e.g., from companies that commission commercial heating, ventilation, and air conditioning (HVAC) systems, and, if appropriate, request data from them.

3. Examine data from the Department of Energy Residential Energy Consumption Survey, the American Housing Survey, and other sources to characterize the existing multi-family building stock in California in terms of age, size, type (multi-use or residential), and other factors. Compare results to the coverage of available air infiltration data to determine which particular building types are over- or under-represented in the data.
4. Analyze the available infiltration data, comparing leakage parameters to building characteristics to determine any trends—i.e., characterize leakiness distributions by building use, size, construction, age, etc.
5. Summarize the current knowledge of air exchange rates as a function of building type and age, and identify gaps in the current knowledge.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound, safe energy.** This project summarizes data on how well California's commercial and multi-family building stock ensures adequate indoor air quality without wasting energy. Where the existing building stock is too "tight," public education or incentives to install ventilation devices can substantially reduce health effects from poor indoor air quality. Where the existing building stock is too "leaky," incentives (or requirements) to improve building insulation and maintenance can save significant amounts of energy, and thus reduce the emissions associated with power generation. This project also contributes to public safety by providing basic information needed to guide "shelter in place" alerts in the event of a chemical disaster.
- **Providing affordable energy.** In single-family houses, close to a third of residents get insufficient outdoor air at least some of the time, and another twenty percent have such high air exchange rates that their heating and cooling costs are more than double what they need to be. The multi-family residences studied in this project were much leakier than houses. Reducing the air exchange rate—e.g., by improving windows and doors—could save hundreds of millions of dollars per year in apartment buildings alone.

Results

Very few data were found from California buildings, so the research team compiled data from other states as well as Canada, the U.K., France, and Sweden. Even then, data were so sparse that few conclusions could be drawn. Only a few buildings were from California, and it is unknown if there is a large difference in leakiness between buildings in California and buildings elsewhere, although buildings in coastal California may be presumed to be leakier due to the mild climate.

Analysis of the commercial buildings data (267 buildings) suggests that:

1. Within a given category of building activity (education, retail, etc.) there appears to be little systematic variation in leakage parameter as a function of construction type.
2. Within a given construction type (metal-frame, masonry, etc.) there is some evidence that schools and public assembly buildings tend to be somewhat tighter than average and that warehouses tend to be leakier than average.

3. For a given building activity and construction type, buildings with small “footprints” (i.e., small roof area) under 1000 m^2 tend to be 25% to 50% leakier, per unit of envelope area, than buildings with large footprints.
4. For a given building activity and construction type, taller buildings appear to be slightly tighter than shorter buildings (with single-story buildings being perhaps 10% to 25% leakier than taller buildings, per unit of envelope area). However, the scarcity of tall buildings in the database provides little statistical power to address this issue, and almost all of the tall buildings are office buildings, so a height effect cannot be distinguished from an effect of construction type.
5. For a given building activity, construction type, footprint size, and height, leakiness per unit of envelope area is approximately lognormally distributed, with a geometric standard deviation (GSD) between about 1.7 and 2.2. (A “lognormal” distribution means that the logarithms of the data are distributed according to a Gaussian, or “normal,” distribution.)
6. On average, commercial buildings may be about twice as leaky as single-family houses, per unit of building envelope area.

The paucity of apartment data—only 162 living units in 78 multi-family buildings in the U.S. and Canada, with only 4 apartments in 2 buildings in California—made it impossible to draw definitive conclusions about infiltration in multi-family housing stock. From the available data, indoor-outdoor air exchange rates and building leakage area per unit of building envelope area seem to be about twice as high (i.e., twice as leaky) as for single-family homes. Multi-family housing may thus represent a large opportunity for energy savings through “weatherproofing” (tightening the building envelope with better windows, doors, insulation, and caulking).

Air quality in multi-family and multi-use buildings may be an even greater concern than energy savings. The literature revealed that much of the air entering apartments comes from elsewhere in the building rather than outdoors. Apartment dwellers may thus be exposed to significant amounts of pollution—such as cigarette smoke or dry cleaning chemicals—originating in other parts of their building.

Final Report

The final report for this project, *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings* (CEC-500-2006-111), is posted on the Energy Commission website at www.energy.ca.gov/2006publications/CEC-500-2006-111/.

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